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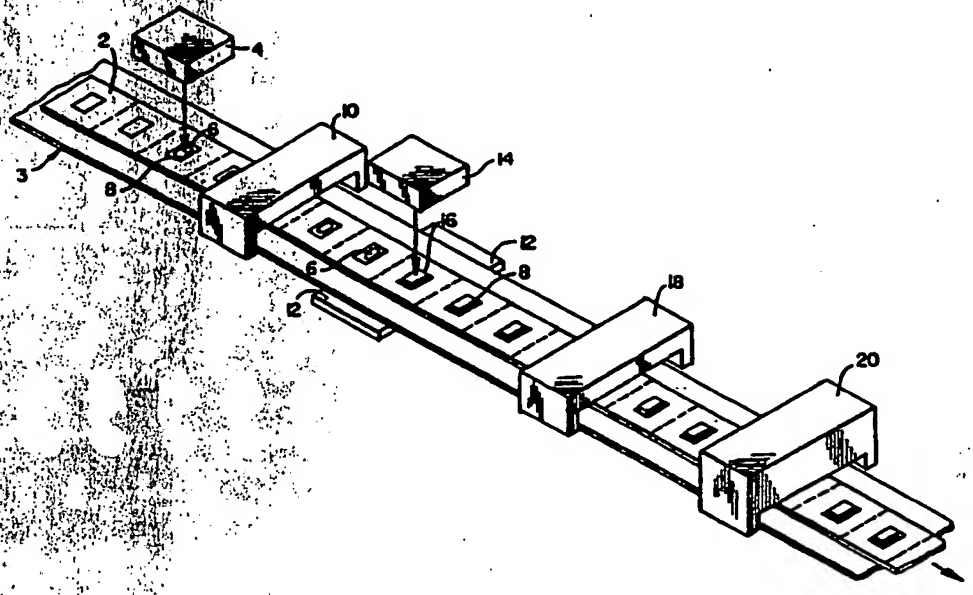
(54) Title: ATTACHMENT OF SEMICONDUCTOR DIE TO LEAD FRAME BY MEANS OF AN ADHESIVE RESIN



(57) Abstract

Semiconductor packages are fabricated by first depositing an adhesive resin (6) c mposition on the paddle (8) of a lead frame (2), activating the adhesive resin by rapidly raising its temperature and then depositing a die (16) on the activated adhesive. Conventional wire bonding and encapsulating steps follow to afford the semiconductor package.

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Attachment of semiconductor die to lead-frame by means of an adhesive resin.

FIELD OF THE INVENTION

This invention pertains to the assembly of semiconductor devices and more particularly to processes and equipment for attaching dies to lead frames using a polymer based die attach adhesive.

BACKGROUND OF THE INVENTION

Assembly-stage processing involving polymer-based hybrid circuits, chip-on-board and other semiconductor devices employ the following general process sequence:

(1) dispensing an adhesive to a substrate (for example, a lead frame) where the adhesive and substrate are at room temperature,

(2) placing the die onto the adhesive,

(3) baking the assembly at 135 ^{o}C to 250 ^{o}C to cure the adhesive,

(4) bonding the wires between the die and points on the substrate to effect electrical contact therebetween, and

(5) encapsulating the die (for example, molding it in epoxy) to complete the package.

Fine gold, gold alloy or aluminum wires are welded to the die pads and leads by:

(1) thermosonic bonding at temperatures ranging from about room temperature to about 300 °C; or by

(2) thermocompression bonding which is a process employing pressure in conjunction with temperatures up to about 300 °C, or above.

As with any line operation, the speed of fabrication and the space required for each separate step are of the essence.

The adhesives used for bonding the dies to the lead frame can be:

(1) electrically conductive

(2) thermally conductive, or

(3) non-conductive

If the design of the semiconductor package uses the back of the die as a ground, an electrically conductive adhesive is needed to enable current to exit from the lead frame.

Alternatively one or more pads can serve as grounds allowing current to exit through the leads. In the latter case thermal or non-conductive adhesives are used as the die bonding material.

The currently used polymer based adhesives in this art are epoxy resins and polyamic acids which are cured to polyimides.

It is an object of this invention to provide an improved method for fabricating semiconductor devices.

It is another object to provide a method which eliminates one or more fabricating steps.

It is still another object to provide a method which shortens the total time required to fabricate a semiconductor device.

It is also an object of this invention to provide equipment or apparatus for carrying out the improved method.

Other objects will become apparent to those skilled in the art upon a further reading of the specification.

SUMMARY OF THE INVENTION

A method has been discovered for improving the fabrication of semiconductor devices which comprises the steps of:

(a) depositing a bonding amount of a polymer-based adhesive composition onto a substrate;

(b) thereafter heating the adhesive composition to activate the adhesive; and

(c) contacting the adhesive with a die, whereby the die is attached to the substrate.

This method lends itself well to attaching a die to a lead frame by:

(1) depositing a bonding amount of a polymer-based adhesive composition on a pre-determined area of a lead frame;

(2) raising the temperature of the polymer-based adhesive composition to a level where said adhesive is activated;

(3) contacting a die containing at least one bond pad with said activated adhesive; and

(4) subsequently, completing the assembly by wire bonding and encapsulation.

Apparatus for carrying out the method above comprises:

(A) transport means for carrying a substrate, such as a lead frame, having distinct die placement areas such as paddles, through a moving in-line assembly operation;

(B) means for dispensing an adhesive onto said die placement areas as the substrate moves through the assembly operation;

(C) optional preheat means for optionally heating the moving substrate;

(D) heating means for heating the adhesive on the substrate;

(E) means for selecting and depositing dies onto the heated adhesive on the substrate; and

(F) optional postheat means for optionally heating the die-adhesive substrate assembly as the substrate moves down the assembly line.

The substrate material of construction is not critical. The substrate therefore can be a metal lead frame, a ceramic or a ceramic package, a ceramic hybrid or a like material.

The heating means for heating the adhesive can be any suitable heating device known to those skilled in the art, as for example, a heated platen, a stream of heated air or nitrogen, a laser beam, an infra-red lamp, and the like. Similarly the post heat means is not limited to any particular means but also can be a heated platen, infra-red heating means, heated air or nitrogen, microwave or induction heaters, and the like.

DESCRIPTION OF THE INVENTION

Figure 1 is a view in perspective schematically delineating the steps of one version of the instant invention using an adhesive paste.

Figure 2 is also a view in perspective of another version of the invention using an adhesive ribbon.

In line equipment useful for the practice of conventional assembly stage processing is commercially available and is known to those skilled in the art. Such equipment can be modified to implement the present invention.

In the practice of this invention, the adhesive is a polymer-based composition; thus, it can be based on a thermoplastic resin as well as a curable or hardenable thermosetting resin. The adhesive can be in the form of a paste, a film, a tape, a foil or a ribbon.

The preferred adhesive resin compositions used herein are the thermoplastic paste or ribbon resin compositions because these compositions tend to result in less residual stress on the chip or die than thermoset or curable products

that undergo chemical reaction during heating.

Pastes are highly viscous, non-solid mixtures of solid particles dispersed in a liquid suspending medium or solvent.

Films, tapes, foils, and ribbons may be distinguished from pastes, rheologically, in that they are not viscous. Tapes, foils and ribbons can be supported or unsupported and can be used with release agents to preclude blocking when being unrolled from a dispenser.

The thermoplastic resin components useful in the practice of this invention should be room temperature stable, flexible, heat activatable and heat resistant. They should not lose their rheological properties at low temperatures or embrittle with age. They preferably should be soluble in organic solvents which can be readily removed without leaving traces of solvent adhering to or complexed with the resin. They should be water resistant, exhibit excellent adhesion to metals and die, accept a high conductivity filler loading and have a low volume resistivity value.

Suitable thermoplastic resins include thermoplastic polyhydroxyethers (phenoxy resins) described in U.S. No. 3,177,090 and 3,395,118; polyimides described in U.S. No. 3,410,875 and 3,615,913; polyarylene polyether polysulfone resins described in U.S. No. 3,933,764 as well as polyphenylene oxides and other low stress, high temperature thermoplastic polarylate resins referred to as structural or high performance adhesive resins.

Thermoplastic resins containing alpha, beta-ethylenically unsaturated hydrocarbon groups polymerized therein which are not corrosive to metals commonly used in semiconductor packages can also be used if their second order transition temperatures are high enough to preclude shifting of dies after being adhesively bonded to a substrate.

Because corrosion is a highly critical factor in semiconductor packages, many commonly used thermoplastic resins cannot be utilized. For example, halogenated vinyls, such as, polyvinyl chloride, polyvinylidene chloride, vinyl chloride-alpha-olefin copolymers, acrylic or methacrylic acid copolymers, chloroprene, acrylonitrile polymers and the like are unsatisfactory.

Preferred as the thermoplastic resin used in the adhesive compositions of this invention are the siloxane-modified polyimides prepared as described in U.S. Patents No. 3,440,527, 3,575,923, 3,875,116 and 4,395,527 the teachings of which are incorporated herein by reference.

The adhesive paste composition comprises:

(a) about 5% to about 75% by weight of the thermoplastic resin and preferably 5% to 85% by weight;

(b) about 25% to about 95% by weight of a thermally or electrically conductive filler and preferably 5% to 75% by weight; and

(c) about 0% to about 50% by weight of an organic solvent and preferably 20% to 50% by weight.

Other additives to adjust viscosity, rheology, tack and other physical properities of the wet paste or dried adhesive can be included in the composition if desired.

The electrically conductive filler can be any metal used in the art, such as, silver, gold, platinum, palladium, iridium, mercury, ruthenium and osmium. Mixtures or alloys of these metals can also be used. However, the preferred metal is silver, either alone or alloyed with platinum or palladium. The electrically conductive filler can also be coated on a glass or ceramic substrate to reduce cost or to modify the properties of the adhesive.

The thermally conductive filler can be beryllia, alumina, silica, oxides of antimony, magnesium, or zinc and the like.

If it is desired to use thermosetting resins as the polymer-based adhesive, one can choose from such commercially available materials as the epoxy resins, polyamic acids, maleimides and the like.

The organic solvents used in these adhesive compositions should dissolve the resins and be volatile enough so that they can be removed easily wihout adhering to the resins. Suitable solvents include derivatives of monoalkyl and/or dialkyl ethers of ethylene glycol and condensed polyethylene glycols and/or cyclic ethers containing no less than a 5-member ring, such as, triethylene glycol dimethyl ether (triglyme), diethylene glycol dimethyl ether (diglyme)

and ethylene glycol dimethyl ether (monoglyme); and N-methyl-2-pyrrolidone, gamma-butryolactone, 2-(2-ethoxy)ethyl acetate (Carbitol acetate), 2-butoxyethyl acetate (butyl Cellosolve), and the like. The preferred solvent is diglyme, particularly when the resin is a siloxane-modified polyimide.
After evaporation of the solvent, the adhesive itself comprises about 5-50% by weight of the resin, preferably 8-30% and 40-95% by weight of the metal, preferably 65-90%.

If desired other materials can be added to the adhesive composition including rheological control agents, inert fillers, colorants and colloidal silica.

The thermoplastic resins useful in formulating adhesive compositions can also be characterized by their second order glass transition temperatures. Such compositions should have a minimum value of 100 ^{o}C and a maximum value of 285 ^{o}C with a range of 150 -250 ^{o}C being preferred.

The molecular weight (number average) of the siloxane-modified polyimide resins is in the range of about 50,000 tc about 200,000.

These thermoplastic resins have high resilience and flexibility characteristics enabling them to bond dies to lead frames in the practice of this invention without danger of stress cracking of the dies. Stress may be considered to be a function of crosslinking causing volume shrinkage which passes stress on to a chip. A creep mechanism enables thermoplastics to relax and to dissipate stress. This is a significant improvement over previously used resins, as for example epoxy resins, bis-maleimide resins, polyamic acid

resins and the like, where the shrinkage which occurs upon curing also contributes to the creation of stress.

The application of the adhesive composition to the pre-designated areas of the lead frame can be effected by the use of a screen print, a syringe or a stamping mechanism (similar to off-set printing) where an arm picks up adhesive from a pot or reservoir and then moves to stamp the adhesive on the lead frame. Mechanical problems, such as, voids or excess adhesive are resolved by programmed automatic dispensing techniques.

An unexpected advantage of the first version of the instant invention over the prior art methods is the time saving achieved by dispensing cold adhesive to a cold lead frame. The heating means raises the temperature of the adhesive paste in 0.5-2.5 seconds, driving out the solvent and leaving a tacky thermoplastic adhesive spot on which the die is placed and bonded. Brief postheating may optimize solvent removal. The lead frame with bonded die is then ready for the finishing steps of wire welding, encapsulation and separation into semiconduuctor packages.

The term "activated" is used in this invention to mean that state at which the resin in the adhesive composition functions to adhesively bond a die to a lead frame. Thus, in the case of an adhesive resin paste composition containing or based on a thermoplastic resin, it is the temperature at which sufficient organic solvent is removed to afford a hot thermoplastic resin with sufficient tack to exhibit adhesive

properties sufficient to bond a die to a lead frame. After activation, these pastes are essentially solids. Where the solvent is diglyme, an effective activation temperature is about 200°C.

In the case of thermosetting resins, they are activated in this invention when they are cured or crosslinked to a state where they function as adhesives for die bonding with or without the release of a solvent or vaporized liquid, such as water generated during the cure of a polyamic acid. Activation temperatures can be from about 175°C to about 350°C.

The above definitions apply to ribbon adhesives as well whether they are based on thermoplastic or thermosetting resins.

This invention lends itself to incorporation in "jelly bean" IC techniques where the assembly lines run flat out at maximum speeds as well as hybrid and chip on board assemblies.

The invention is further described in the examples that follow. All parts and percentages are by weight unless otherwise specified.

EXAMPLE 1

Referring to Figure 1, lead frame, 2, is passed as part of belt feed system, 3, in proximity to an adhesive composition dispensing means, 4, which can be screen printing, a syringe or a print stamper which deposits small premeasured portions of a polymer-based adhesive paste composition, 6, at room temperature on the paddle, 8, of lead frame, 2. The lead frame containing deposited paste composition, 6, passes through optional pre-heat means, 10, and then on to heated platen, 12, where the temperature of the paste composition, 6, is quickly raised to a temperature high enough to activate the adhesive. Where the solvent is diglyme this temperature can be from about 50°C to about 200°C. At this point, a transfer arm from die dispensing means, 14, deposits a die, 16, on the heated paste composition, 6, adhering to lead frame paddle, 8. The composite of die, 16, bonded to paddle, 8, on lead frame, 2, passes through an optional heating means, 18, or directly without optional heating means, 18, to an apppropriate collector, such as a magazine, 20, en route to the wire bond step.

The die shear strengths of the die bonds obtained by using a filled thermoplastic polyimide composition (described in U.S. Patent 4,395,527 which is incorporated herein by reference) with this method are shown below and exceed those required by the specification MIL-STD-883C.

TEST	VALUE
Initial die shear strength, kg	8.0
Die shear after 1,000 hours @ 150 °C.	5.0
Die shear after 250 hours pressure pot (121 °C, 15 psig)	7.5
Die shear after 1,000 hours (85 °C/85/ R.H.)	6.0

The thermal properties of the die bonds obtained by this method are presented below.

TEST	VALUE
Thermogravimetric Analysis in air @ 400 °C; % weight loss.	3.8
Loss after 16 hours @ 250 °C in air	2.5
Residual stress on IC, meters	>15
ASTM Thermal Conductivity, in BTU/hr-ft^2 (°F/ft)	0.47
Maximum wire bond Temp., °C	225

The electrical properties of the resultant die bonds are given below.

TEST	VALUE
Resistivity, ohm-cm as baked	9.0×10^{-5}
,000 hours @ 150°C	8.3×10^{-5}
50 hours	9.0×10^{-5}
e pot(121°C, 15 psig)	
,000 hours	9.0×10^{-5}
% R.H.	

EXAMPLE 2

With reference to Figure 2, a lead frame, 22, is rted as part of a belt feed system, 24, through an I heating means, 26, to a position in contact with platen, 28, where the temperature of the paddle, 30, ed rapidly to a temperature high enough to activate ticular adhesive being used. For a thermoplastic resin dhesive, this temperature will be from about 250°C to 50°C. Ribbon adhesive dispensing means, 32, equipped guillotine and applicator, 34, cuts and deposits a tab sive, 35, onto heated paddle, 30. Immediately thereaf- transfer arm of die dispensing means, 36, places a , on the tab of heated and activated adhesive adhering le, 30. The composite of die, 37, bonded to paddle, lead frame, 22, passes on belt feed system, 24,

through optional heating means, 38, or by-passes optional heating means, 38, going to a collector or magazine, 40, in preparation for the wire bonding step.

The invention described herein is preferably carried out in a continuous manner although it may also be practiced in an intermittently if so desired.

Although the invention has been described in its preferred forms with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes can be made without departing from the spirit and the scope of this invention.

CLAIMS

1. A method of attaching a die to a substrate which comprises the steps of:

(a) depositing a bonding amount of a polymer-based adhesive composition onto a substrate;

(b) thereafter heating the adhesive composition to activate the adhesive; and

(c) contacting the activated adhesive with a die, whereby the die is attached to the substrate.

2. Method claimed in claim 1 in which the adhesive composition is in the form of a paste.

3. Method claimed in claim 2 in which the adhesive composition is heated to a temperature of about 175 °C to about 350 °C.

4. Method claimed in claim 3 in which the adhesive paste comprises a thermosetting polymer composition.

5. Method claimed in claim 4 in which the adhesive paste composition-thermosetting polymer composition comprises an epoxy or a maleimide resin.

6. Method claimed in claim 2 in which the adhesive paste comprises a thermoplastic polymer composition.

7. Method claimed in claim 6 in which the adhesive paste thermoplastic polymer is a thermoplastic polyimide.

8. Method claimed in claims 6 or 7 in which the adhesive paste is heated from about 50 °C to about 200 °C to effect activation.

9. Method claimed in claim 1 in which the adhesive composition is in the form of a film or ribbon.

10. Method claimed in claim 9 in which the adhesive composition is heated to a temperature of from about 175 °C to about 350 °C.

11. Method claimed in claim 1 in which the substrate comprises a metal lead frame.

12. Method claimed in claim 1 in which the substrate comprises a ceramic.

13. Method claimed in claim 12 in which the substrate comprises a ceramic hybrid substrate.

14. Method claimed in claim 12 in which the substrate comprises a ceramic package.

15. Method claimed in claim 1 in which the substrate comprises a circuit board.

16. Method claimed in clam 2 in which the composition comprises:

5-75% of resin

25-95% of filler

0-50% of solvent

17. Method claimed in claim 6 in which the composition comprises:

5-85% of thermoplastic resin

25-75% of filler

20-50% of solvent

18. Method claimed in claim 17 in which the filler comprises an electrically conductive filler.

19. Method claimed in claim 18 in which the electrically conductive filler is a metal selected from the class consisting of silver, gold, platinum, iridium, mercury, ruthenium, osmium and mixtures or alloys thereof.

20. Method claimed in claim 17 in which the filler comprises a thermally conductive filler.

21. Method claimed in claim 20 in which the thermally conductive filler is beryllia.

22. Method claimed in claim 20 in which the thermally conductive filler is alumina.

23. Method claimed in claim 1 in which the assembly of substrate, adhesive and die is further heated.

24. Method claimed in claim 1 in which the method is carried out in a continuous manner.

25. A method for attaching a die to a metal lead frame which comprises:

(a) depositing a bonding amount of a thermoplastic polymer-based adhesive composition in paste form on the paddle area of the lead frame;

(b) thereafter heating the adhesive composition to a temperature of about 50 °C to about 200 °C to activate the adhesive;

(c) placing a die onto the activated adhesive; and

(d) optionally further heating the assembly of lead frame, adhesive and die, whereby the die is bonded to the lead frame.

26. Method claimed in claim 25 in which the method is carried out in a continuous manner.

27. A method for attaching a die to a metal lead frame which comprises:

(a) depositing a bonding amount of thermoplastic polymer-based adhesive composition in ribbon or film form on the paddle area of a lead frame;

(b) thereafter heating the adhesive composition to about 250°C-350°C to activate the adhesive;

(c) placing a die onto the activated adhesive; and

(d) optionally further heating the assembly of lead frame, adhesive and die, whereby the die is bonded to the lead frame.

28. Method claimed in claim 27 in which the method is carried out in a continuous manner.

29. An apparatus for attaching a die to a substrate with a polymer-based adhesive which comprises:

(a) transport means for moving a substrate through the apparatus;

(b) optional means for heating the substrate prior to dispensing the adhesive;

(c) means for dispensing the adhesive composition onto a selected area of the substrate;

(d) heating means for heating the adhesive prior to placement of the die;

(e) means for selecting and placing a die onto the heated adhesive; and

(f) optional means for postheating the assembly of substrate, adhesive and die.

30. The apparatus claimed in claim 29 in which the adhesive is in paste form.

31. The apparatus claimed in claim 29 in which the adhesive is in film or ribbon form.

32. The apparatus claimed in claim 29 in which the heating means for heating the adhesive comprises a heated platen.

33. The apparatus claimed in claim 29 in which the heating means for heating the adhesive comprises a stream of heated air.

34. The apparatus claimed in claim 29 in which the heating means for heating the adhesive comprises a laser.

35. The apparatus claimed in claim 29 in which the heating means for heating the adhesive comprises an infra-red lamp.

36. The apparatus claimed in claim 29 in which the post heat means comprises one or more heated platens.

37. The apparatus claimed in claim 29 in which the post heat means comprises infra-red heating means.

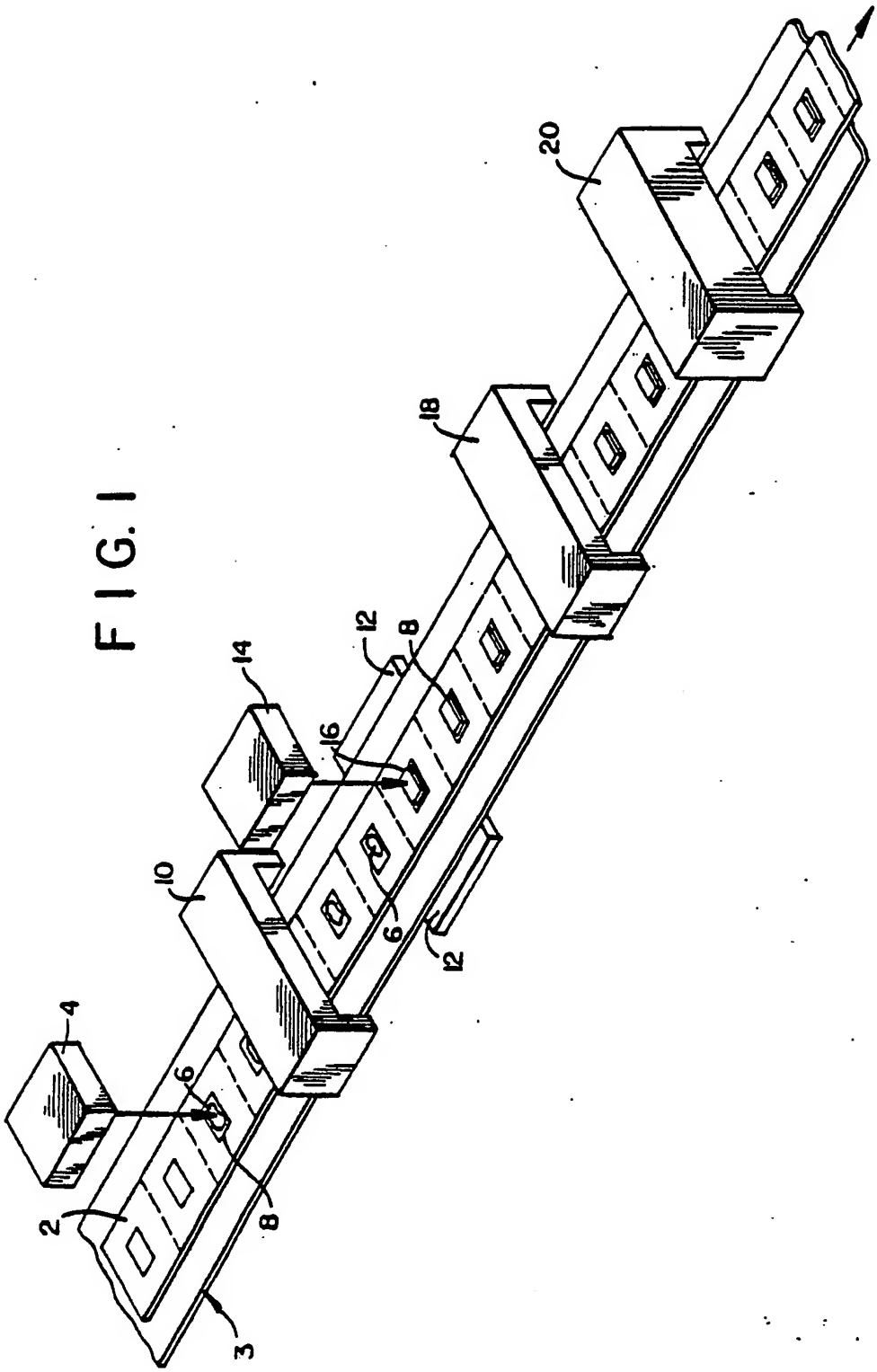

FIG. 1

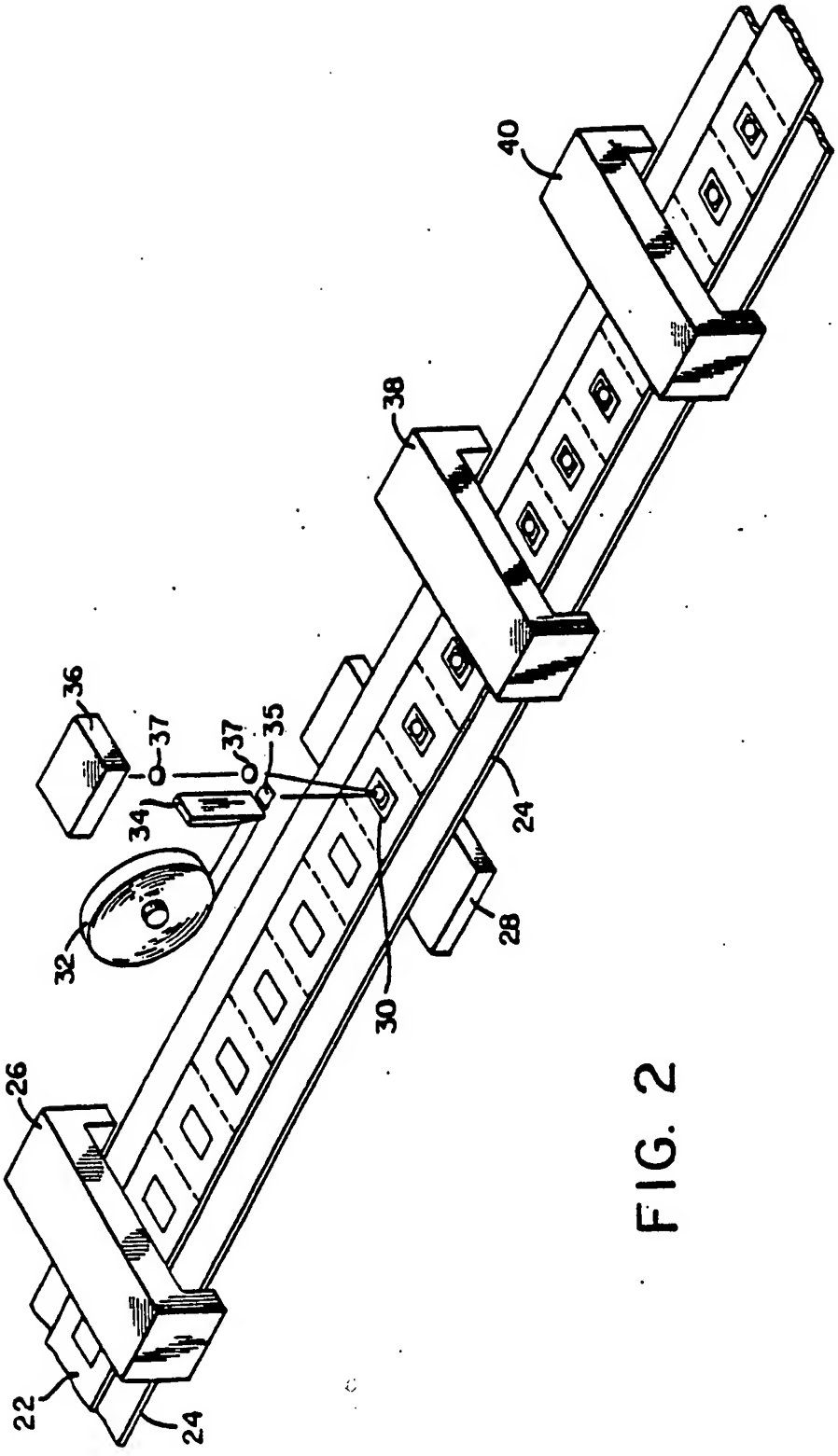

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 87/02952

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: H 01 L 21/58

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	H 01 L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	EP, A, 0051165 (BURROUGHS) 12 May 1982 see page 7, line 11 - page 11, line 6; figure 2	1,12,14, 15
Y		2-8,16-20, 24,25,27,28
A		29-37
	--	
Y	US, A, 4029628 (FREDBERG) 14 June 1977 see the whole document	2-8,16-20, 25
	--	
Y	Patent Abstracts of Japan, volume 9, no. 173 (E-329)(1896), 18 July 1985, & JP, A, 6045030 (HITACHI KASEI KOGYO K.K.) 11 March 1985 see the abstract	9-11,24, 27,28
	--	
X	Patent Abstracts of Japan, volume 8, no. 81 (E-238)(1518), 13 April 1984, & JP, A, 59931 (MITSUBISHI DENKI K.K.) 6 January 1984 see the abstract	1
A		25,27

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
4th February 1988	06 APR 1988
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 8702952 SA 19624

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 12/03/88
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0051165	12-05-82	JP-A- 57104234	29-06-82
US-A- 4029628	14-06-77	None	

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